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The Evolution of Saturn's Stratospheric Beacon 2011-2012

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Abstract

The slow warming of Saturn's springtime stratosphere was spectacularly disrupted in 2010 by the eruption of a planetary-scale tropospheric storm system [1-3]. The roiling, convective motions of the tropospheric cloud decks had a dramatic influence on the atmospheric temperatures and composition many hundreds of kilometers higher up, in Saturn's stably stratified middle atmosphere. Energy transported from the tropospheric storm was deposited in two warm stratospheric airmasses, known as beacons B1 and B2 because of their brightness in thermal infrared imaging. These features were observed throughout 2011 and 2012 using a combination of 7-1000 µm spectroscopic mapping from the Cassini Composite Infrared Spectrometer (CIRS, [1]) and filtered 7-25 µm imaging from the VLT/VISIR and IRTF/MIRSI thermal-infrared instruments. These infrared observations are used to discuss the motions, temperatures, composition, winds and stability of these newly discovered phenomena in Saturn's stratosphere.

1. Beacon Observations

Beacon one (B1) was more extended and located directly above the convecting storm head in the troposphere, moving west at 2.73±0.1 deg/day. The second beacon (B2) was more compact and at a more southerly latitude, moving west at 0.6±0.1 deg/day. This difference in drift rates caused the two beacons to encounter one another in late April 2011, when they behaved as two coherent anticyclonic vortices and merged, forming a single large beacon complex (B0) at 39^{o}N (Fig. 1).

This single beacon was an elongated oval of high temperatures, some 50'000 km wide and stretching from 25-55^{o}N, with peak temperatures in the centre of B0 of 221.6±1.4 K at 2 mbar on May 5th 2011, some 80 K warmer than the quiescent stratosphere. B0 became disassociated from the tropospheric storm head, which disappeared by July 2011, but continued to propagate westward at 2.68±0.04 deg/day, a retrograde velocity comparable to the tropospheric jet velocity hundreds of kilometres below. Despite the high temperatures of the stratospheric beacon, we observed no perturbations to tropospheric cloud decks or upper tropospheric/lower stratospheric hazes during the observation period – these phenomena can only be observed in thermal emission.

2. Temperature Measurement

Optimal estimation retrievals of atmospheric temperatures, using the suite of remote sensing and inversion codes developed at Oxford to invert the

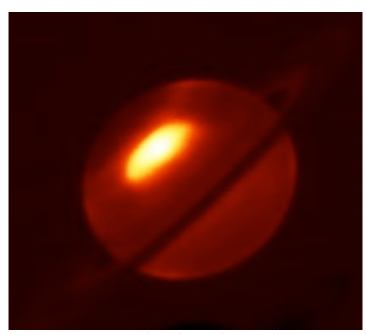

Figure 1 Bright emission from Saturn's beacon B0 on July 24th 2011, two months after merger. VLT/VISIR filtered imaging at 13 µm.

Cassini/CIRS 7-16 μm spectra (Nemesis, [4]), show that the merger of B1 and B2 was associated with a downward shift in the peak temperatures from 0.5 mbar pre-merger to 2 mbar post-merger, a translocation of approximately 85 km or 1.7 scale heights. Such a downward shift may partially explain the enhancement in stratospheric acetylene (derived from the 13-μm emission band) by a factor of three within the beacon. However, no comparable variations of stratospheric ethane have been detected, suggestive of unusual photochemistry occurring within the beacon.

Thermal windshears calculated from temperature mapping demonstrate anticyclonic vorticity (clockwise rotation) with peripheral velocities of 170-200 m/s at 1 mbar, consistent with clockwise circulation of the beacon. Although B0 shows some evidence for shrinking (160-K contours are shrinking longitudinally by 0.16±0.01 deg/day) and cooling (peak temperatures have decreased by approximately 0.11±0.1 K/day), its westward motion is remarkably predictable, and this unusual phenomenon remains present at the time of writing (May 2012).

3. Summary

The origins and evolution of this large warm airmass in Saturn's stratosphere appears to be a new phenomenon of giant planet middle atmospheric dynamics. The mechanism coupling a deep convective storm system in the troposphere to the thermal structure of the stratosphere is uncertain, but most likely to be the result of waves propagating radially outwards and upwards from the storm head. Many questions remain unresolved. Will the beacon complex fade and cool over the coming months, returning Saturn's stratosphere to its usual, seasonally evolving conditions? Are these stratospheric beacons common features of Saturn's seasonal storms (the Great White Spots), or of convective plumes in generalised gas giant atmospheres? Does the seasonal modulation of the temperature field [5] control the size and extent of stratospheric perturbations arising from tropospheric storms? Any new convective storms during Saturn's northern summer season (solstice in 2017) will be intensively scrutinised by Cassini and ground-based observatories to answer these questions.

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